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HABITAT USE BY BREEDING MALE NORTHERN GOSHAWKS IN NORTHERN ARIZONA

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Abstract. We radio-tagged and followed 5 and 9 male northern goshawks (Accipiter gentilis atricapillus) during the breeding seasons of 1991 and 1992, respectively, to evaluate their use of different forest conditions in managed ponderosa pine (Pinus ponderosa) forests in northern Arizona. Sufficient data for habitat analyses were collected for 11 birds, located a total of 734 times. Mean size of the home-ranges was 1,758 ha (SD=500 ha, range 896 - 2528 ha) calculated by the minimum convex polygon method and 1,530 ha (SD=477 ha, range 859 - 2,321 ha) calculated by the 95% harmonic mean method. We compared use (i.e., number of hawk locations) of several categories of forest conditions to the availability (i.e., % of area of home range) of these categories for three different overlays (canopy closure, edge, and diversity) generated from LANDSAT data. Most (≥6) of the 11 birds used the categories in the three overlays approximately in proportion to their availability. Six of the 11 birds used at least one category on one of the overlays nonrandomly. Of these, three hawks used forests with relatively closed canopies more than expected, three used areas with relatively open canopies less than expected; four used woodland >200 m from edge more than expected; and one used areas with a high diversity of categories less than expected. When categories of canopy closure were ranked for each bird on the basis of relative preference, average rank increased with increasing canopy closure.

Key words: northern goshawk; Accipiter gentilis, home-range; habitat use; LANDSAT imagery.

INTRODUCTION

Efforts to maintain habitat for the northern goshawk (Accipiter gentilis atricapillus) in managed forests in western North America have focused on retaining stands of relatively large, old trees for nesting sites (see Reynolds 1987). More complete conservation strategies for goshawks also need to address environments used for other activities, such as foraging (Reynolds 1983, Crocker-Bedford 1990). Current recommendations for managing forests for northern goshawks in the southwestern U. S. call not only for maintaining nest stands, but also for developing forest environments that support a variety of their prey species in a 2,430 ha-area surrounding each nest (Reynolds et al. 1992).

Information from North America about the kinds of forest conditions used by foraging goshawks is limited. Fisher and Murphy (1986) radio-tracked a breeding pair of goshawks in Utah and concluded that the male occupied habitat nonrandomly by foraging predominantly in mature stands of Douglas-fir-white fir (Pseudotsuga menziesii - Abies concolor) forest. Austin (1993) radio-tracked 10 goshawks (5 males and 5 females) in northern California and found that they occupied meadows and stands of seedlings and saplings less than expected, and mature forest stands (dominant trees $\geq$ 52 cm in diameter at breast height, canopy closure $\geq$ 40%) more than expected, based on availability.

Kenward (1982) found that the European goshawk (A. g.

gentilis) spent a disproportionately large amount of time in woodlands during the breeding season in agricultural areas of England and Sweden. In Sweden, goshawks used woodlands within 200 m of edge but avoided both unbroken woodland and extensive open areas (Kenward 1982). Widen (1989) radio-tracked goshawks in an intensely managed boreal forest in Sweden that contained a patchwork of stands of differing ages. Widen (1989) found that males and females both foraged in relatively large (>40 ha) tracts of forest >60 years of age.

Our objective in this study was to compare the availability and use of different forest conditions within the home-ranges (Johnson 1980) of nesting male goshawks during the breeding season. Our null statistical hypothesis was that male goshawks use forest conditions within their home ranges randomly.

STUDY AREA

The study was conducted on the North Kaibab Ranger District (NKRD), Kaibab National Forest, on the Kaibab Plateau in northern Arizona. The district encompasses approximately 259,000 ha and is located north of Grand Canyon National Park. Elevation of the NKRD ranges from 1,060 to 2,800 m. Topography of the plateau is typified by gentle slopes interspersed with shallow to steep drainages. Vegetation on the plateau is characterized by mixed-conifer forest (white fir, blue spruce [Picea pungens], Douglas-fir, and quaking aspen [Populus tremuloides]) at the highest elevations, ponderosa pine forest between 2,075 and 2500 m, and

pinyon-juniper-oak woodland (Pinus edulis-Juniperus spp.-Quercus spp.) at lower elevations. A detailed description of the plateau is given by Rasmussen (1941). We selected hawks for study that nested in areas dominated by ponderosa pine (about 99,200 ha on the plateau).

METHODS

TELEMETRY

Personnel from the USDA Forest Service and Arizona Game and Fish Department had located nests of goshawks throughout the Kaibab Plateau prior to this study. We chose hawks to study based on four criteria: sex of the bird, topography and roads in the area around the nest, and forest type. Only males were studied because they provide between 80% and 90% of the prey consumed by the nestlings and because females spend the first half of the nestling period on or near the nest (Schnell 1958, Snyder and Wiley 1976, Reynolds and Meslow 1984, Kennedy 1991). Males were chosen from nests in areas that were relatively flat (although all areas were transversed by drainages), were dominated by ponderosa pine, and had a good system of roads. Flat areas with good roads were chosen to allow easy access to an entire home-range. The hawks studied were not chosen randomly and therefore their use of forest conditions may not reflect that of the population of goshawks on the plateau.

Birds were trapped with two kinds of traps. Falling-end Swedish goshawk traps (Kenward and Marcstrom 1983) baited with

two or more pigeons were placed outside the nest stand within three km of the nest and checked every two hours. These traps were used during incubation to reduce disturbance at the nest. After the eggs hatched and the risk of abandonment by the adults decreased, dho-gaza traps (Clark 1981) baited with a live great horned owl (Bubo virginianus) were placed within 50 m of the nest as recommended by Bloom (1987).

Captured goshawks were banded with a U.S. Fish and Wildlife Service band and a color band, and fitted with a two-stage radio transmitter (model TW-2 from BIOTRACK). The transmitters had posture-sensitive activity switches, weighed almost 10 g, (less than 2% of the body weight of the birds), and were attached to tail feathers (Kenward 1978).

We located marked birds from 13 June through 10 August 1991 and 8 June through 9 August 1992. Monitoring began at least 36 hours after the radios were attached to allow the birds to become accustomed to the transmitter. During 1991, we tracked birds for one 4-hour period a day and attempted to locate the birds every half hour during this period. We rotated the 4-hour periods so that each bird was monitored at different times of the day. In 1992, we attempted to locate each bird twice a day. Locations were obtained so that they were evenly distributed among all the daylight hours. The change in data collection was made to maximize the number of independent locations (Schoener 1981, Swihart and Slade 1985a) we could collect.

Locations were obtained by one of two methods: direct observation and triangulation. All direct observations of marked birds were recorded directly onto U.S. Geological Survey (USGS) topographic maps. For locations obtained by triangulation, two observers with hand-held yagi antennas approached the bird until the sound of the signal at a specified gain value became distorted (approximately 50-200 m away). The observers then took positions which gave an angle to the bird between the two observers of 45 to 135 degrees. The observers then recorded the bearing to the bird and mapped their location on 7.5" USGS topographic quads with the aid of a compass and by pacing to identifiable topographic features. Location of the bird was assumed to be where the 2 bearings crossed. Actions were coordinated between the observers with hand-held radios. Activity switches on the transmitters allowed observers to avoid attempting to triangulate on moving birds. Observers did not approach within 200 m of the nest while radio-tracking because the presence of humans near the nest caused the male to remain in the area, disrupting his normal activities.

ESTIMATION OF LOCATION ERROR

We estimated the error associated with triangulations by following a protocol similar to that described by White and Garrott (1990) for estimating error of locations from airplanes. Transmitters were placed in a variety of topographic positions, stand conditions, and microsites to simulate locations of

goshawks. Microsites included brush piles, logs, snags, and tree branches 0 to 10 m from the ground. The locations of the "test" transmitters were mapped by pacing and/or triangulating from known locations and visible topographic features. The error associated with the mapped locations of the "test" transmitters was small because they were placed near features that were clearly identifiable on topographic maps.

A pair of observers who did not place the "test" transmitter then located it by triangulation, following the procedure outlined above. Locations based on triangulation were converted to universal transverse mercator (UTM) coordinates. The UTM coordinates of the triangulated position were then compared to the UTM coordinates of the position mapped by the team placing the transmitter. The distance between the triangulated position and the mapped position was then calculated and considered the error associated with location of that "test" transmitter. This distance incorporates error associated with triangulation and error associated with mapping the location of the observers. An average error for "test" transmitters was calculated for each year. We assumed that the average error associated with the location of the "test" transmitters was similar to the error associated with the location of hawks. Distances also were calculated from each observer to the triangulated location of the "test" transmitters and the hawks.

HOME-RANGE

Home-range sizes were calculated using the minimum convex polygon (MCP) (Mohr 1947) and harmonic mean (HM) (Dixon and Chapman 1980) methods. All data, regardless of the time interval between consecutive locations were used for the MCP calculations because this method does not require statistically independent locations (Swihart and Slade 1985b). For 1991, HM home-ranges were calculated with a subset of the data that was not autocorrelated. We selected the subset by calculating the time to independence to the nearest 15 min. with the Schoener ratio (Schoener 1981, Swihart and Slade 1985a). The non-autocorrelated data set was generated by selecting locations that were separated by the minimum time to independence (135 min.). All of the data for 1992 were used to calculate HM home-ranges because the time between locations was much greater than the time to independence determined in 1991. The grid size used in the calculation of harmonic mean home-ranges was larger than the average error associated with the locations. Area-observation curves (Odum and Kuenzler 1955) were generated for each home-range to ensure that the average increase in home-range size was below 5% for the last 10 locations recorded (Fuller and Snow 1988).

HABITAT CATEGORIES

Digital elevation data (DEM) for the Kaibab Plateau were obtained from the USDA Forest Service, Kaibab National Forest. These data were used to create a slope map for the study area so that we

could examine goshawk use of topographic positions (i.e., flat areas versus drainages). The slope map was classified into seven slope categories (1=0-2%, 2=3-5%, 3=6-10%, 4=11-15%, 5=16-20%, 6=21-25%, and 7=>26%).

Satellite imagery from LANDSAT 5 was obtained from 22 June 1991. This scene included no cloud cover over the study area. We used the satellite imagery to identify forest conditions within the home-ranges of the goshawks we studied. Our general approach was to classify the imagery and then assess what the classes represented with aerial photographs. We allowed the computer to search for "natural" groupings of spectral properties (i.e., an unsupervised classification [Jensen 1986:215]) produced by the reflectance in bands 3, 4, and 5. This procedure was conducted in the Geographical Resources Analysis Support System (GRASS) with a maximum likelihood discriminant analysis classifier. Cell size was 30 m by 30 m for all analyses.

Fifteen classes with different spectral signatures (i.e., different forest conditions or vegetative composition) were delineated. We overlaid a map of the 15 classes on a sample of aerial photographs taken in July 1991 (scale 1:8000) to visually ascertain what the classes represented in terms of forest conditions. We found that, with one exception, the classes (1-15) corresponded to a continuum of increasing forest density. Our relatively small sample of hawk locations prevented us from evaluating use of 15 different classes so we lumped the classes

into 5 categories that broadly represented the following forest conditions: (1) bare ground or occasional trees, (2) open savannah-like conditions, (3) open overstory with a dense deciduous understory (this category was the exception mentioned above and was distinguished primarily on the basis of vegetative composition), (4) moderate overstory, and (5) dense overstory.

We then used the aerial photos to define each of the 5 categories on the basis of canopy closure and to estimate how consistently measures of canopy closure separated the 5 categories. We chose canopy closure to define the categories because this measure appeared to reflect a major difference among the categories and could be estimated from aerial photos. For each home-range for which aerial photos were available (n = 7), one photo was randomly chosen for examination. We first outlined the areas of all five categories on the seven photos. We then estimated canopy closure by measuring the amount of intercept of tree crowns along 199 lines each 20 mm long. The lines were randomly placed on the photos with the restrictions that they fall within the boundary of one category and not be within 2.5 cm of the edge of the photos. The later restriction was to reduce the effects of lens distortion. We used a single eye piece magnifier (7X lens) with a 20 mm bar scale on an attached reticle to make the measurements. Canopy closure was calculated as the percent of the 20 mm line intercepted by tree crowns. Crowns of all trees were included in the estimates because it was difficult

to separate crowns of small and large trees when they were clustered together. Patches consisting of only small trees also were included, but were considered a source of error (see below).

The boundaries of the five categories were defined to maximize the percent of line estimates in each category that would be correctly classified. Definitions were: (1) 0-15% canopy closure (CC); (2) 15-33% CC; (3) <33% ponderosa pine canopy closure with a dense understory of aspen, oak, or locust; (4) 34-55% CC; and (5) >55% CC.

The accuracy of defining the 5 categories on the basis of canopy closure was estimated as the percent of the total number of line estimates for each category that fell in the ranges given above. One problem we noted was that dense stands (>0.36 ha) of seedlings and small trees were classified as >55% CC. We measured the area of these stands on the sample of aerial photographs to obtain an estimate of how much they contributed to the total area of the >55% CC category (n=37 patches totalling 40.0 ha) and added this to percent misclassification. Based on these estimates, we determined that measures of canopy closure from aerial photographs accurately defined 84% of the <15% CC category, 72% of the 15-33% CC, 79% of the 34-55% CC, and 83% of the >55% CC (Table 1). The category with <33% ponderosa pine overstory with an understory of oak, locust, or aspen occurred too rarely to adequately assess accuracy or use in statistical analyses so it was lumped with the 15-33% CC category.

Because measures of canopy closure from aerial photographs likely overestimate canopy closure on the ground (see Brunnell and Vales 1989), we made some preliminary measurements on the ground to quantify the potential bias. Sixty-nine transects, each 100 m long, were laid out in areas representing four categories (17 in the <15% CC, 34-55% CC, and >55% CC categories, and 18 in the 15-33% CC category). Areas sampled and position of the transects were chosen randomly. Canopy closure was estimated along the transects by determining the percent of each transect that was covered by the crowns of overstory trees (i.e., crown intercept). Preliminary measurements on the ground confirmed that our canopy closure categories represented areas with increasing canopy closure, but suggested that our measurements from aerial photographs overestimated canopy closure (measurements of canopy closure from the ground: <15% CC, $\bar{x}$=4.1%, range=0-11.8%; 15-33% CC, $\bar{x}$=15.4, range=0-32.1%; 34-55% CC, $\bar{x}$=34.7%, range=17.4-49.7%; >55% CC, $\bar{x}$=48.3, range=22.2-78.2%).

The map of canopy closure categories (i.e., canopy closure overlay) was used as a base map to create a habitat diversity overlay, a basic habitat overlay, and an edge overlay. The diversity map was created by performing a 5x5 cell neighborhood analysis on the canopy closure overlay. Each cell was about 30 m on a side so this analysis counted the number of different canopy closure categories found in a 2.25 ha square centered on a cell. Areas that were uniform (1 CC category), or had low (2 CC

categories), moderate (3 CC categories), or high (4 or 5 CC categories) diversity were outlined on the diversity overlay.

The basic habitat overlay (HAB) was created in two steps. First, an overlay was made by smoothing the original canopy closure overlay. Smoothing consisted of two iterations of a 3x3 cell neighborhood analysis in which each cell of the new overlay was assigned the value of the most commonly occurring class in the 9 cell neighborhood. The smoothed overlay was then combined with a map from the USDA Forest Service that showed areas that were dominated by pinyon-juniper woodland. The resulting map (HAB) was the same as the smoothed habitat map except that all pinyon-juniper woodland was assigned a new value. The area of pinyon-juniper was too small to allow its inclusion in the statistical analyses so based on its average canopy closure it was lumped with the 15-33% CC category.

The HAB overlay was used as the starting point to create the edge overlay. The 34-55% CC and >55% CC categories from the HAB overlay were lumped as "woodland" and the remainder of the classes were lumped as "open areas." The edge overlay was created by defining five new categories: open areas, woodland within 50 m of an open area, woodland 50-100 m from an open area, woodland 100-200 m from an open area, and woodland greater than 200 m from an open area.

ANALYSIS OF HABITAT USE

We included all independent locations of goshawks that were

perched or observed flying below the canopy in the analyses of habitat use. We do not know what portion of the locations represented foraging behavior because we could not determine what the birds were doing in most instances. We assumed that our data would reflect the relative value of the categories for foraging. We made this assumption because we collected data during the nestling and fledgling periods, when foraging demands are highest and males must capture prey for the female and nestlings in addition to satisfying their own needs.

Analyses of use (i.e., number of hawk locations) versus availability (i.e., % of total area of a home range) were conducted for each bird at 2 scales for each overlay, and then trends in relative preference among all birds were evaluated for each overlay. For the first scale, we compared the number of hawk locations in each habitat category to the number expected if the hawks were using the categories randomly (i.e., based on the availability of the categories in the MCP home-range). Second, we compared the area of each habitat category in 90 m radius circles centered on the locations of birds (i.e., used) to the area of each category available (i.e., expected) in the MCP home-range. A radius of 90 meters was chosen for 3 biological reasons and 1 practical reason. First, information from Europe suggests that A. g. gentilis may forage near edges (Kenward 1982) and we did not want to throw out all locations near edges, as has been done by some (e.g., Call et al. 1992). Second, for some

overlays, as many as 3 or 4 habitat categories occurred within 90 m of a hawk location and, given the error associated with triangulations, assigning all the weight to one category could bias the results. Finally, goshawks do not forage only at a single point but scan the surrounding area for potential prey. This idea is supported by Kenward (1982) who found that attack flights averaged 54 m from perch to prey in woodland and 103 m in open areas. The value of 90 m was chosen because it was an even multiple of the 30 m cell size.

A Chi-square goodness of fit test was used to test use versus availability for the habitat and slope categories for individual birds, as discussed by Thomas and Taylor (1990). When Chi-square tests were significant ($P < 0.05$), Bonferoni 95% confidence intervals were calculated to determine which categories differed from expected (Neu et al. 1974). For the 90-m circle analyses, the observed value for the Chi-square test was calculated for a habitat category by summing the proportion of the area of each circle that was in that habitat category.

Patterns of habitat preference among all birds were evaluated by averaging the rank preferences of all hawks for each habitat category (i.e., a Friedman's test [Ott 1988]) as discussed by Alldredge and Ratti (1992) and Conover (1980) with one modification. Instead of testing the rank of the difference between the percent used and the percent available for each category, as done by Aldredge and Ratti (1992), we tested the

rank of the relative preference (Chesson 1983) for each category. We used relative preference, as defined below, because it accounted for differences in availability of each habitat category among birds, and allowed us to compare the ranks of relative preferences among birds with different home ranges.

Relative preference was defined for each bird as follows:

$$\frac{Oi/Ei}{\sum_{i=1}^{n}(Oi/Ei)},$$

where Oi = the observed proportional use of habitat category i, Ei = the expected proportional use of habitat category i, and n = the number of habitat categories used by one bird.

The resulting preference values have a range of 0 to 1 and sum to 1 for each bird. These values were ranked for each bird so that the least "preferred" habitat was given a value of 1 and the most "preferred" a value of 4 or 5 depending on the number of habitat categories. Mean ranks were then compared among habitat categories. When the Friedman's test was significant (i.e., a difference among mean ranks was detected), Fisher's least significant difference was calculated to determine which mean rankings differed significantly. For the remainder of the paper when we discuss which habitats are most or least preferred we shall be referring explicitly to the relative preference as defined above.

RESULTS

ERROR

The average error associated with triangulations was 98.3 m (n= 48 test transmitters, SD 134.0) in 1991, and 68.5 m (n=116 test transmitters, SD=58.2) in 1992, probably because the observers were better trained in 1992. In 1991, observers were significantly closer to test transmitters when they took bearings ($\bar{x}_t$=80.3 m, SD=60.9) than they were to birds when they took bearings ($\bar{x}_b$=183.6 m, SD=145.3, P<0.001), but in 1992 there was no difference in this distance ($\bar{x}_t$=158.8, SD=84.5, $\bar{x}_b$=162.9, SD=82.6, P>0.5). We assumed in these calculations that the birds were located at the point where the bearings crossed. The average error associated with the locations was less than the numbers given above because 45.7% of the locations were determined from direct observations.

HOME-RANGE

Transmitters were attached to five birds in 1991 and nine birds in 1992. Twelve of the 14 marked birds successfully fledged young in the year they were studied. Area-observation curves indicated that we obtained a sufficient number of locations to calculate home-ranges for 11 birds (Table 2).

The average size of the MCP home-ranges for the 11 birds was 1,758 ha (SD=500, range 896 - 2528, Table 2). The average size of the 95% HM home-ranges was 1,530 ha (SD=477, range 859 - 2,321 Table 2).

HABITAT USE

The number of locations used for the habitat analyses for each bird was the same as the number of locations used to calculate the 95% HM home-ranges ($\bar{x}$=55.5, SD=16.0, range 35-80, Table 2).

Slope

There was no preference for slope among the birds studied. Only one of the 22 tests on individual birds showed any difference between use and availability of slope categories.

Locations

Eight of the 11 birds used the canopy closure categories in proportion to their occurrence, whereas the remaining three birds (numbers 136, 141, and 223) occupied canopy closure categories within their home-ranges nonrandomly (Table 3). These three birds all used areas with >55% CC more than expected (based on availability) and areas with <15% CC less than expected ($P < 0.02$) (Table 3). One of these birds (number 141) also used areas with 34-55% CC less than expected (Table 3). Six of the 11 birds used the edge categories randomly, and the remaining five birds (numbers 141, 237, 274, 273, and 223) used them nonrandomly (Table 4). Four of these five birds (numbers 237, 274, 273, and 223) used open areas (all areas with <34% CC) less than expected, one (number 141) used areas between 50 and 100 m from edge less than expected, one (number 273) used areas between 100 and 200 m from edge more than expected, and two (numbers 141, 223) used areas greater than 200 m from edge more than expected ($P < 0.05$)

(Table 5). Only one of the 11 birds (number 141) used the diversity categories nonrandomly and this bird used areas of high diversity less than expected (Table 5).

Mean rank of relative preference of the canopy closure categories generally increased with increasing canopy closure (T_2 = 9.28, df_1 = 3, df_2 = 30 $\underline{P}$<0.001, Tables 6, 7). No difference in relative preference was shown for woodland with regard to distance from open areas, but open areas (<34% CC) were preferred less than woodland (areas with ≥34% CC) (T_2 = 6.56, df_1 = 4, df_2 = 40 $\underline{P}$<0.001, Table 8). There was also no difference in relative preference for the diversity categories (T_2 = 2.45, df_1 = 3, df_2 = 30 $\underline{P}$>0.1).

90 M RADIUS CIRCLES

Only one bird (number 223) used areas with less than 15% CC less than expected ($\underline{P}$ < 0.02) (Table 3). Only three birds occupied edge categories nonrandomly (Table 4). Two (numbers 273 and 223) used open areas less than expected and one (number 141) used woodland >200 m from edge more than expected ($\underline{P}$ < 0.05) (Table 4). Only one bird (number 141) used areas of high diversity less than expected (Table 5).

Mean rank of relative preference of the canopy closure categories increased with increasing canopy closure (T_2 = 18.50, df_1 = 3, df_2 = 30 $\underline{P}$<0.001, Table 6, 7). There was no clear pattern in relative preference for woodland categories with respect to distance from open areas, but open areas were

preferred less than woodland areas (T_2 = 10.49, df_1 = 4, df_2 = 40 $\underline{P}$ < 0.001, Table 8). There was no difference in preference among the categories of the diversity overlay (T_2 = 1.36, df_1 = 3, df_2 = 30, $\underline{P}$ > 0.25).

DISCUSSION

HOME-RANGE

The sizes of home-ranges found in this study are intermediate compared with those found by Eng and Gullion (1962) in Minnesota (one male, 1272 ha), Kennedy (1989) in New Mexico (three males, $\bar{x}$=2106, range=1696-2837 ha), and Austin (1993) in California (five males, $\bar{x}$=2425 ha, range=1083-3902). However, comparisons among these studies should be done with caution because the hawks were tracked for different periods of time and/or different methods were used to calculate home-range size.

HABITAT USE

The main pattern we found in the use of forest conditions by goshawks was that mean rank of relative preference of all hawks increased with increasing canopy closure. We do not know the reason for the increased relative preference of goshawks for areas with relatively high canopy closure, but among the potential explanations are the availability of prey (Kenward 1982, Reynolds et al. 1992) and the morphological adaptations of goshawks that presumably make them well adapted for hunting in forests. Fisher and Murphy (1986) and Austin (1993) also found that goshawks used forests with relatively closed canopies more

than open woodlands or meadows.

In contrast to the pattern suggested by the ranking of relative references, our analyses of habitat use by individual hawks indicated that most used forest conditions within their home ranges randomly. The following factors may have reduced our ability to detect significant habitat preferences at the individual bird level: (1) goshawks were more easily observed in open areas than in forests and about half of our locations were direct observations; (2) goshawks were more easily located when they are near roads (usually relatively open areas near edges); (3) our sample of locations for each bird was relatively small; (4) not all individuals have strong habitat preferences within their home ranges; and (5) goshawks may select habitat variables we did not measure. Significant trends at the individual bird level also may have been obscured by the error associated with our locations, the uncertainty about what the birds were doing when we located them, and the error introduced when we smoothed the basic habitat overlay. Smoothing results in small patches potentially being misclassified.

MANAGEMENT RECOMMENDATIONS

We suggest that tree harvest methods that create large areas with sparse tree cover are potentially detrimental to northern goshawks nesting in ponderosa pine forests, especially if the percent of open forests (<34% CC, as measured from aerial photos) in a home range exceeds 35% (the mean found in this study).

Therefore, in areas being managed for northern goshawks, selection cuts and other harvest methods that leave a substantial portion of the canopy intact should be favored. Reynolds et al. (1992) recommended maintaining 40% canopy closure over 60% of a proposed foraging area (2,187 ha) for each pair of nesting goshawks. Our findings support the idea of maintaining relatively high canopy closure over a significant portion of areas managed for foraging goshawks, but our measures of canopy closure can not be used to directly assess the values recommended by Reynolds et al. (1992) because we made our measurements from aerial photos.

Our investigation examined only males during the breeding season. Much information on habitat use is needed, especially on females, immatures and wintering males before a more complete assessment of goshawk habitat requirements can be made. Future researchers should be aware that, as Kenward (1982) and Reynolds et al. (1992) suggested, goshawk habitat selection may be a function of habitat selection by prey species. For this reason, detailed diet analyses should be done in conjunction with studies of habitat use and prey availability if we are to more fully understand the requirements of the northern goshawk.

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TABLE 1. Accuracy matrix for the classification of LANDSAT imagery into canopy closure categories within northern goshawk home-ranges on the Kaibab Plateau, northern Arizona, 1991 and 1992. The table compares the agreement among categories identified in an unsupervised classification (Jensen 1986:215) of LANDSAT imagery and measurements of canopy closure made on aerial photos.

		Aerial Photo Canopy Closure			
LANDSAT Categories		<15%	15-33%	34-55%	>55%
<15%	(31)[a]	0.84	0.13	0.03	0.00
15-33%	(52)	0.13	0.72	0.15	0.00
34-55%	(47)	0.00	0.19	0.79	0.02
>55%	(69,37)[b]	0.00	0.03	0.14	0.83

[a] Number of canopy closure estimates used to calculate percentages.

[b] Number of canopy closure estimates used to calculate percentages and number of stands of dense seedlings/saplings measured.

TABLE 2. Size of home range (ha) and average percent increase for the last 10 locations in the area-observation curve (%A/O) for 11 male northern goshawks on the Kaibab Plateau, northern Arizona, in 1991 and 1992.

Bird	Year Studied	% A/O	MCP Home-Range Size	MCP Home-Range n	95% HM Home-Range[a] Size	95% HM Home-Range[a] n
66	1991	0.0	2444	86	2322	55
136	1991	3.3	1502	87	1041	39
141	1991	4.1	2528	59	1939	47
223	1992	3.7	1450	36	1020	35
237	1991	0.2	1630	42	1279	40
273	1992	0.0	1454	80	1191	80
274	1991	0.2	1478	68	1889	45
285	1992	0.3	2139	84	1903	79
333	1992	0.0	2190	59	1559	59
339	1992	2.8	897	60	860	60
342	1992	0.1	1623	73	1830	72
191	1992	68.4[b]	431	13	518	13
239	1992	NA[c]	14	9	393	9
292	1992	5.3	178	32	1439	32

[a] Sample sizes given under this column are also the sample sizes used for the habitat analyses. HM=harmonic mean; MCP=minimum convex polygon.

[b] Birds with a % A/O of greater than 5.0 were not included in the results of the home-range or habitat portion of this study.

[c] Not applicable.

TABLE 3. Use of canopy closure categories by northern goshawks in ponderosa pine forests on the Kaibab Plateau, northern Arizona, 1991 and 1992. Habitat use was evaluated for goshawk locations and 90 m circles around these locations using the Chi-square test and Bonferroni inequalities (Neu et al. 1974). Only birds that used the categories non-randomly are presented.

	Percent Canopy Closure				
Bird	<15	15-33	34-55	>55	P Values
136	-/0[a]	0/0	0/0	+/0	0.01/0.3
141	-/0	0/0	-/0	+/0	0.02/0.1
223	-/-	0/0	0/0	+/0	0.01/0.02

[a] - = areas used less than expected, 0 = used as expected, += used more than expected. Results are presented for locations/ 90 m radius circles.

TABLE 4. Use of woodland by male northern goshawks with respect to distance from open areas on the Kaibab Plateau, northern Arizona, 1991 and 1992. Habitat use was evaluated for goshawk locations and 90 m circles around these locations with the Chi-square test and Bonferroni inequalities (Neu et al. 1974). Only birds that used the categories non-randomly are presented.

		Woodland Distance From Open Areas				
Bird	Open[a]	0-50m	50-100m	100-200m	>200m	P Values
141	0/0[b]	0/0	-/0	0/0	+/+	0.01/0.01
237	-/0	0/0	0/0	0/0	0/0	0.02/0.5
274	-/0	0/0	0/0	0/0	0/0	0.05/0.8
273	-/-	0/0	0/0	+/0	0/0	0.01/0.05
223	-/-	0/0	0/0	0/0	+/0	0.001/0.001

[a] Includes pinyon-juniper woodland and categories with less than 34% canopy closure.

[b] - = areas used less than expected, 0 = used as expected, + = used more than expected. Results are presented for locations/ 90 m radius circles.

TABLE 5. Habitat use by northern goshawks with respect to diversity of forest canopy closure categories on the Kaibab Plateau, northern Arizona, 1991 and 1992. Habitat use was evaluated for goshawk locations and 90 m circles around these locations with the Chi-square test and Bonferroni inequalities (Neu et al. 1974). Only the 1 bird that used the categories non-randomly is presented.

Bird	Uniform[a]	Low[b]	Moderate[c]	High[d]	P Value
141	0/0[e]	0/0	0/0	-/-	0.01/0.01

[a] This area included 1 habitat category.

[b] This area included 2 habitat categories.

[c] This area included 3 habitat categories.

[d] This area included 4 or 5 haibtat categories.

[e] - = areas used less than expected, 0 = used as expected, += used more than expected. Results are presented for locations/ 90 m radius circles.

TABLE 6. Ranks of relative preference of four canopy closure categories for 11 male northern goshawks during the breeding seasons of 1992 and 1992 on the Kaibab Plateau, northern Arizona (1 = least preferred and 4 = most preferred; results are presented for location/90 m circle analyses).

	Percent Canopy Closure			
Bird	<15	15-33	34-55	>55
66	1/1	3/3	2/2	4/4
136	1/1	3/3	2/2	4/4
141	1/1	3/2	2/3	4/4
223	2/2	1/1	3/3	4/4
237	1/1	3/3	4/2	2/4
273	1/1	2/2	4/4	3/3
274	1.5/2	1.5/1	3/3	4/4
285	1/1	2/2	3/3	4/4
333	3/1	2/3	1/2	4/4
339	3/3	2/1	1/2	4/4
342	1/1	2/2	4/4	3/3

TABLE 7. Mean values for the rank of relative preference of four canopy closure categories for 11 male northern goshawks during the breeding seasons of 1991 and 1992 on the Kaibab Plateau, northern Arizona. *P*-values for the Friedman test are provided. Means that do not significantly differ, as determined by Fisher's least significant difference, share a common underline.

	Percent Canopy Closure					
Analysis	<15	15-33	34-55	>55	n	P
90 m circles	1.36	2.09	2.73	3.82	11	0.001
Locations	1.50	2.23	2.64	3.64	11	0.001

TABLE 8. Mean values for the rank of relative preference with respect to distance from open areas (<34% canopy closure) for 11 male northern goshawks during the breeding seasons of 1991 and 1992 on the Kaibab Plateau, northern Arizona. P-values for the Friedman test are provided. Means that do not differ significantly, as determined by Fisher's least significant difference, share a common underline.

	Woodland Distance From Open Areas						
Analysis	Open	0-50m	>200m	50-100m	100-200m	n	P
90 m circles	1.09	2.91	3.45	3.59	3.95	11	0.001
Locations	1.27	3.18	3.23	3.54	3.73	11	0.001

APPENDIX I

Figures 1-11 presented below depict the home ranges of the male goshawks we studied on the Kaibab Plateau, northern Arizona, in 1991 and 1992. Also depicted are the distribution of hawk locations and categories of canopy closure.

Figure 1. Home range of goshawk number 66, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1991. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

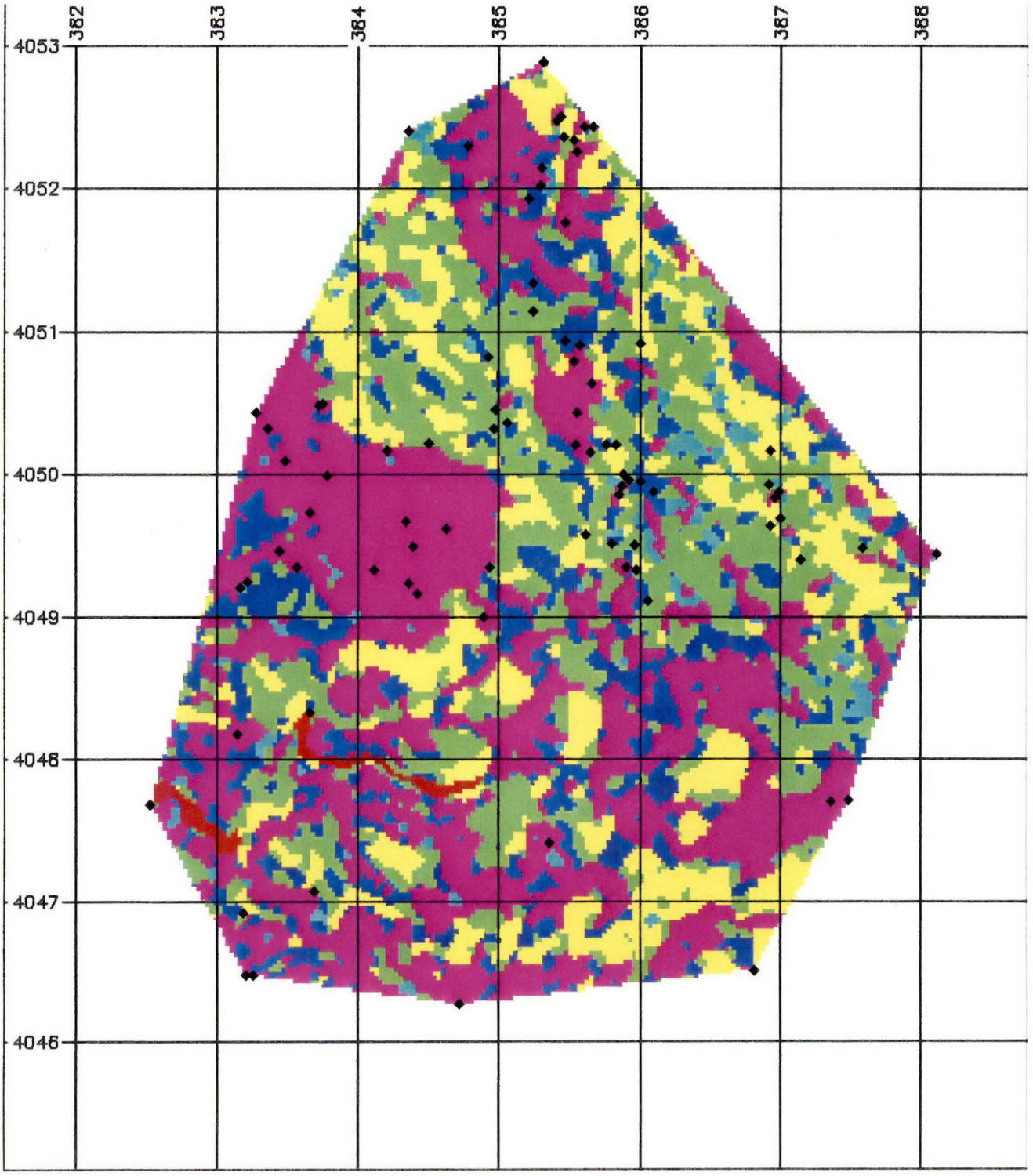
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Figure 2. Home range of goshawk number 136, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1991. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

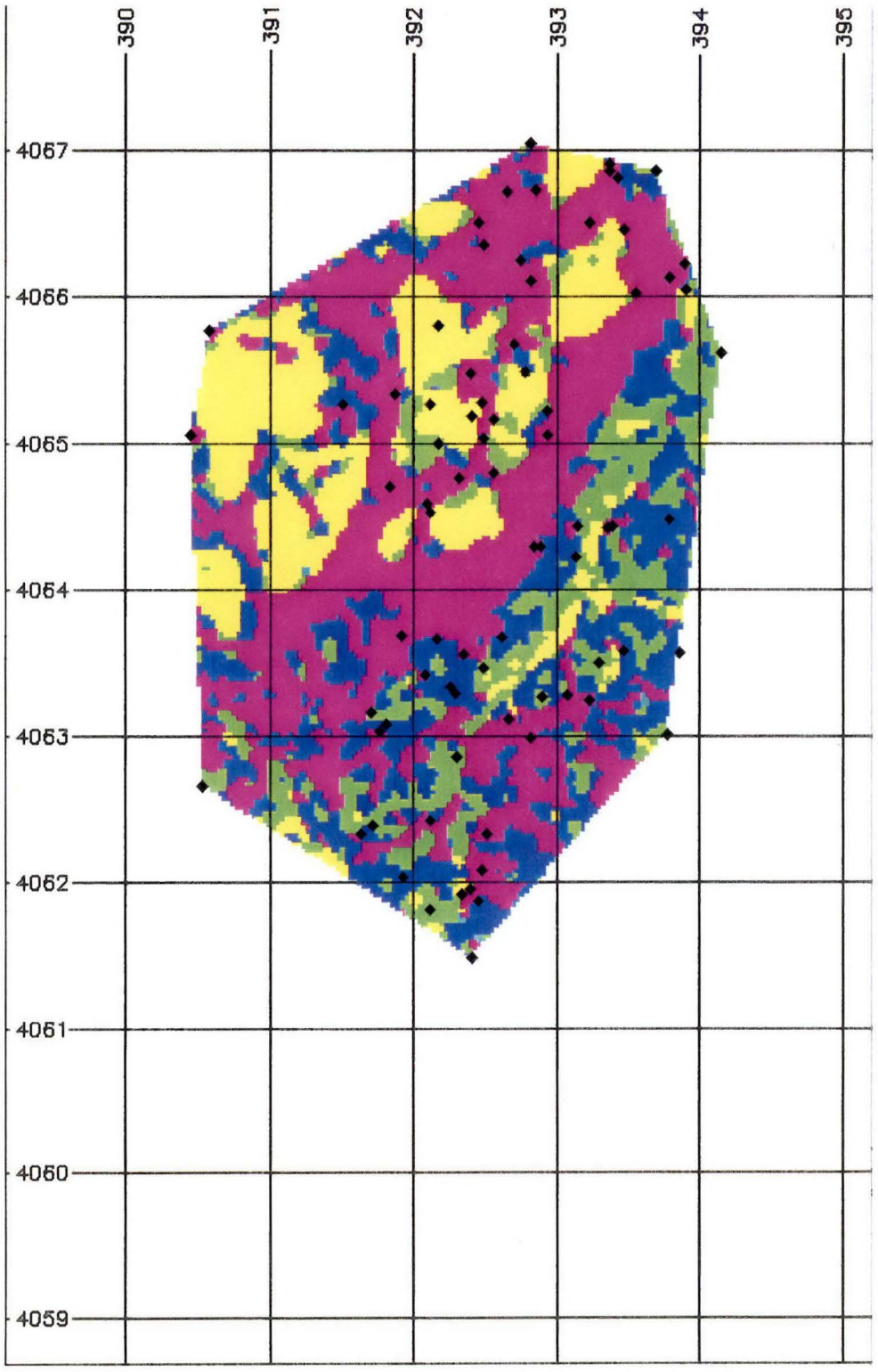
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Figure 3. Home range of goshawk number 141, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1991. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

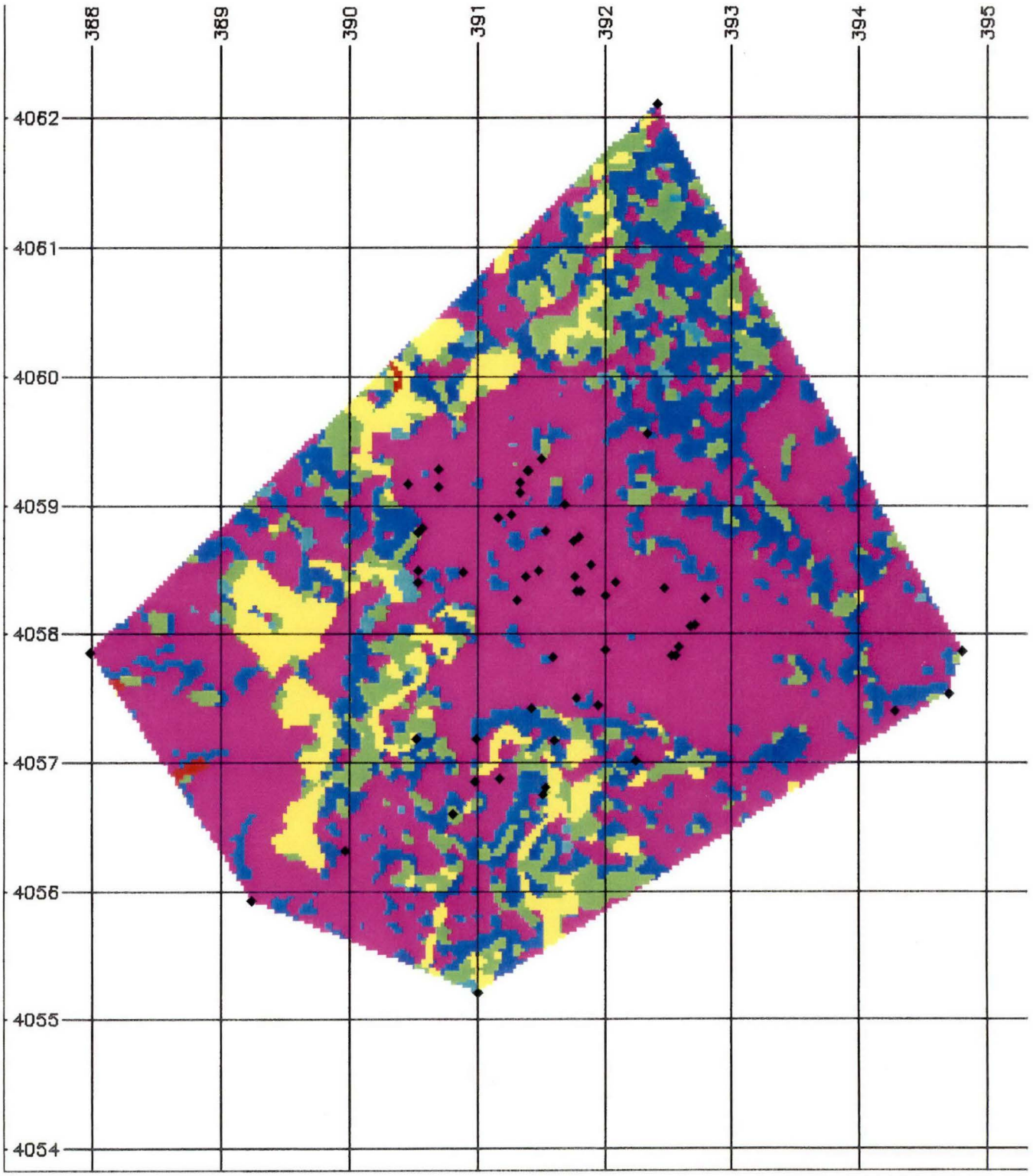
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Figure 4. Home range of goshawk number 223, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1992. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

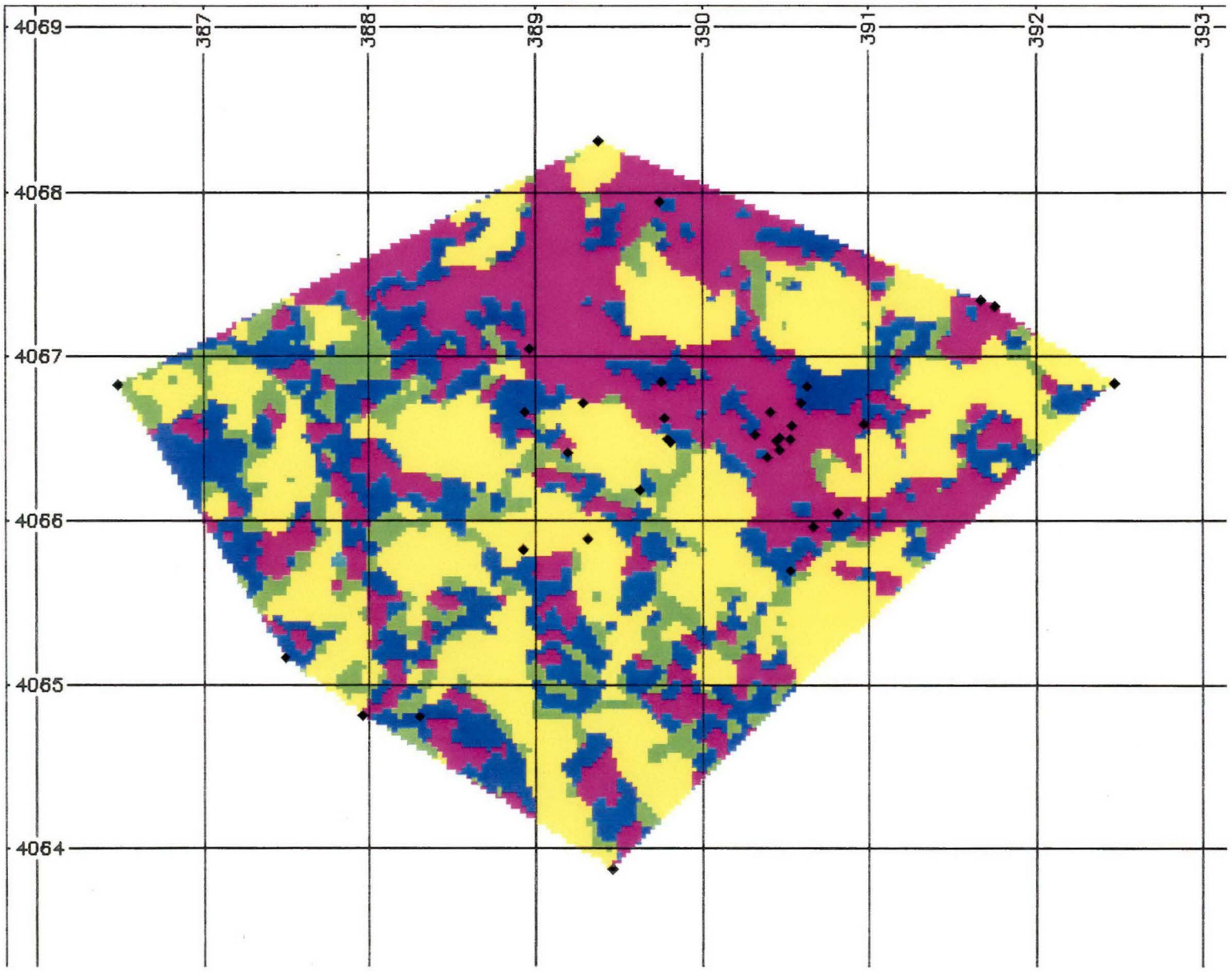
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Figure 5. Home range of goshawk number 237, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1991. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

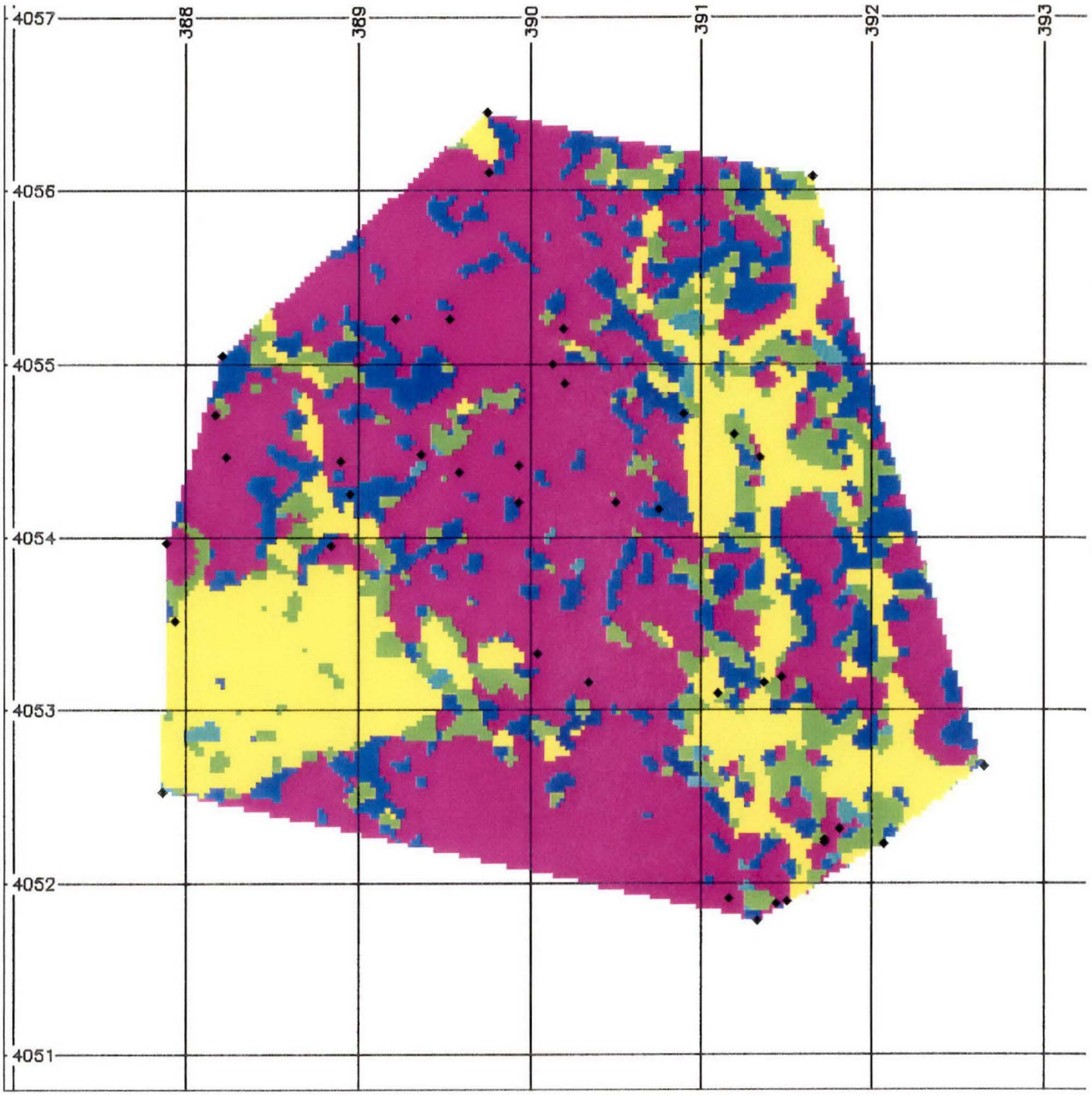
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Figure 6. Home range of goshawk number 273, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1992. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

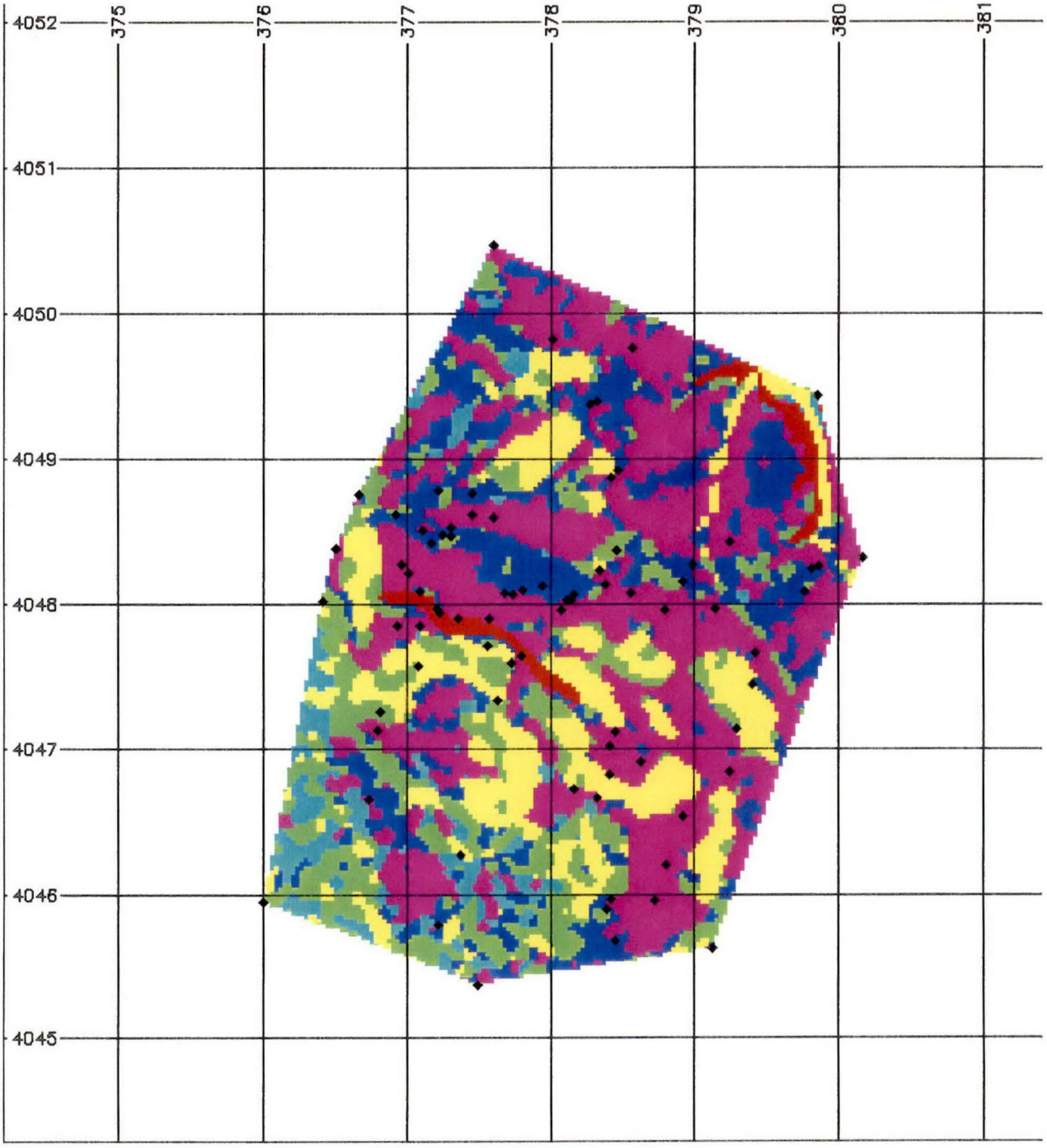
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Figure 7. Home range of goshawk number 274, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1991. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

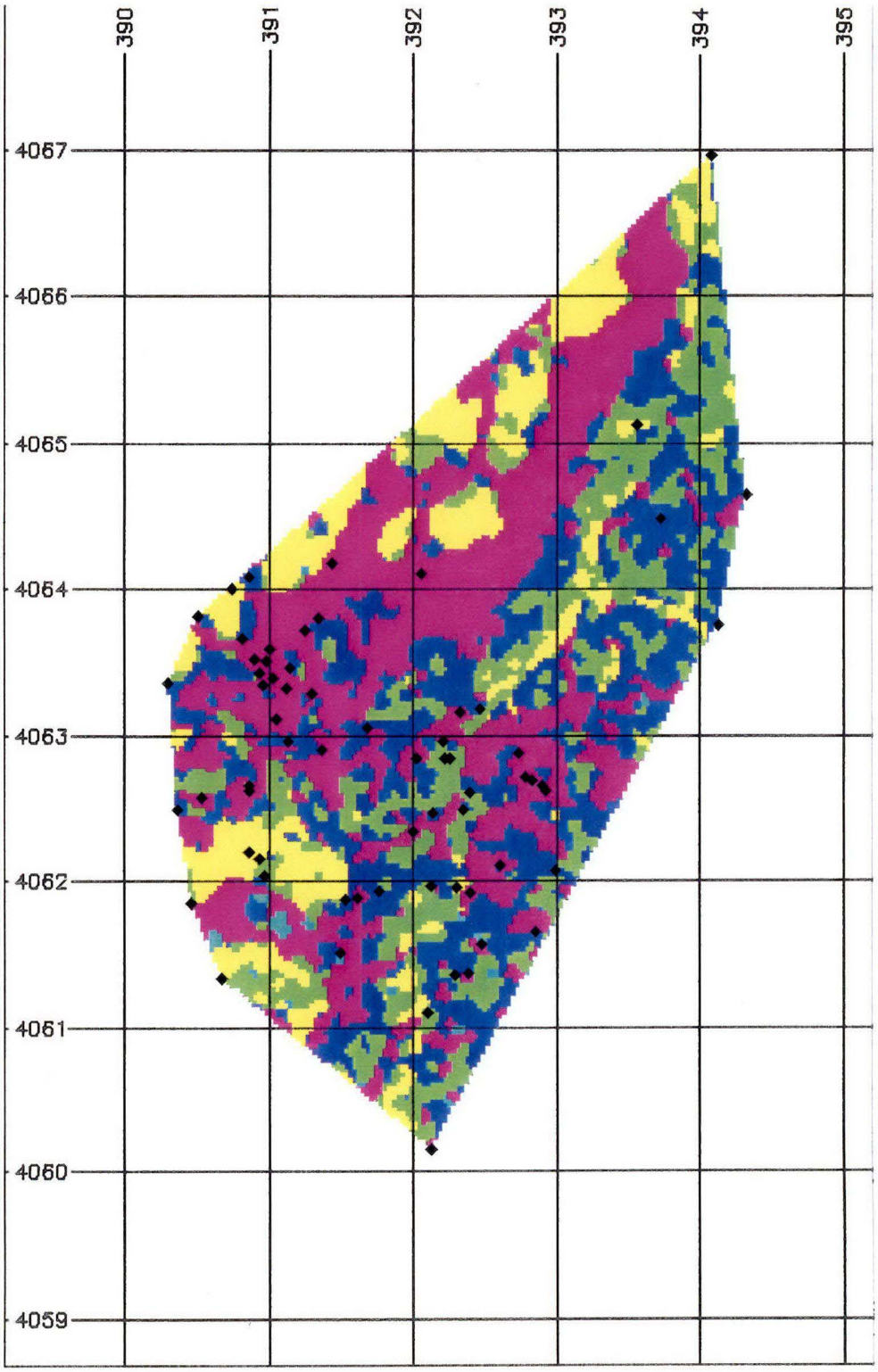
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Figure 8. Home range of goshawk number 285, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1992. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

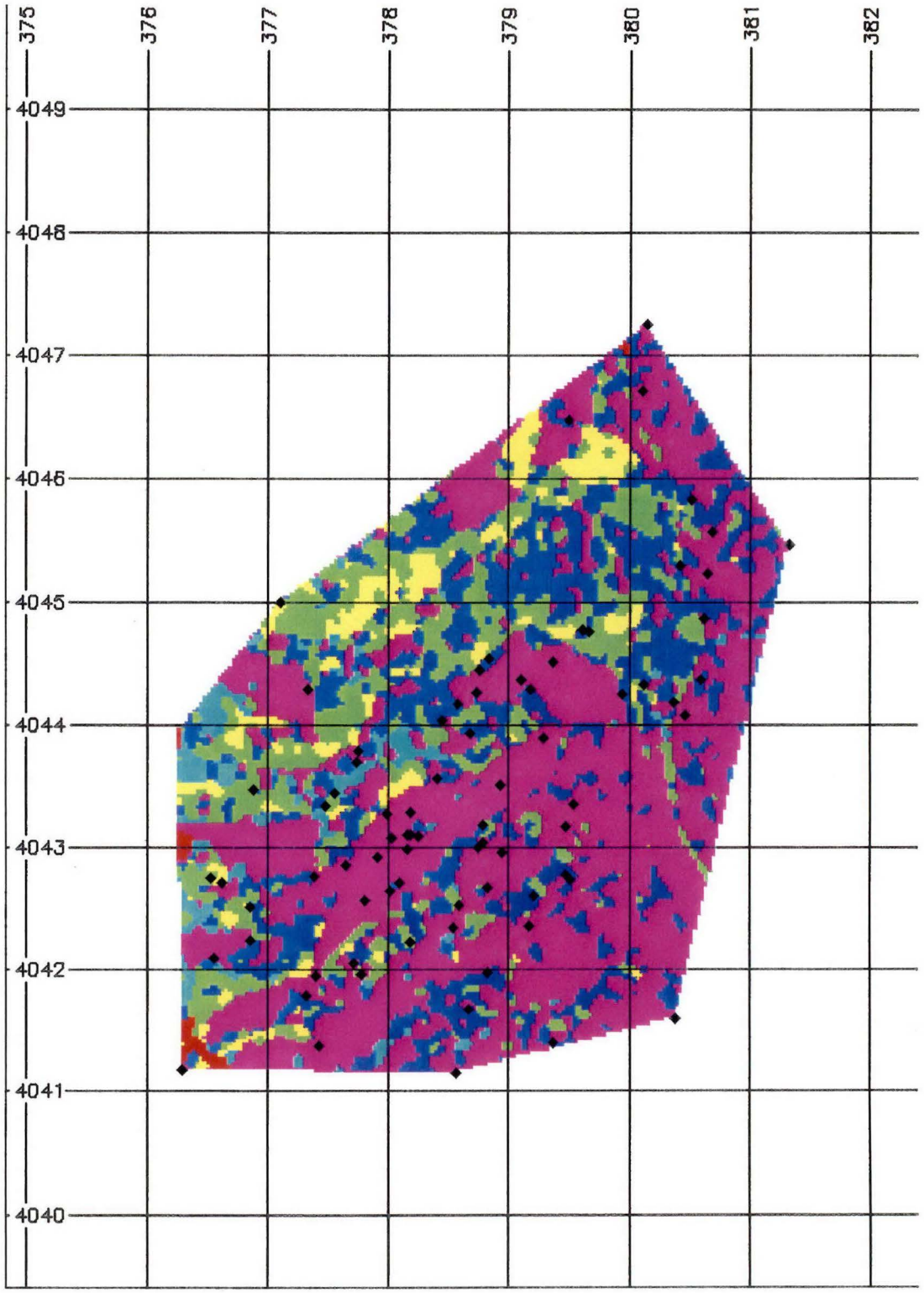
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Figure 9. Home range of goshawk number 333, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1992. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

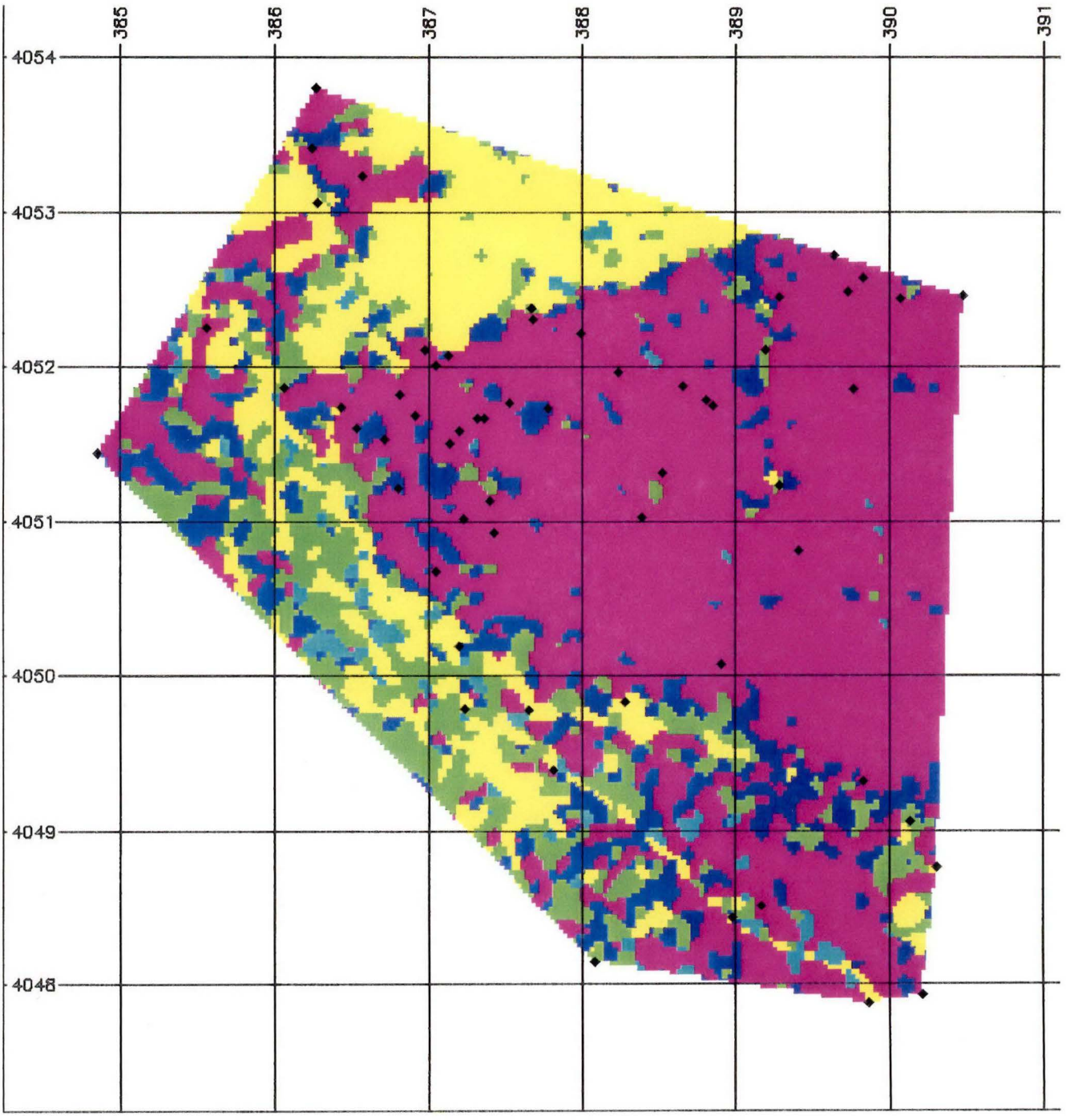
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Figure 10. Home range of goshawk number 339, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1992. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.

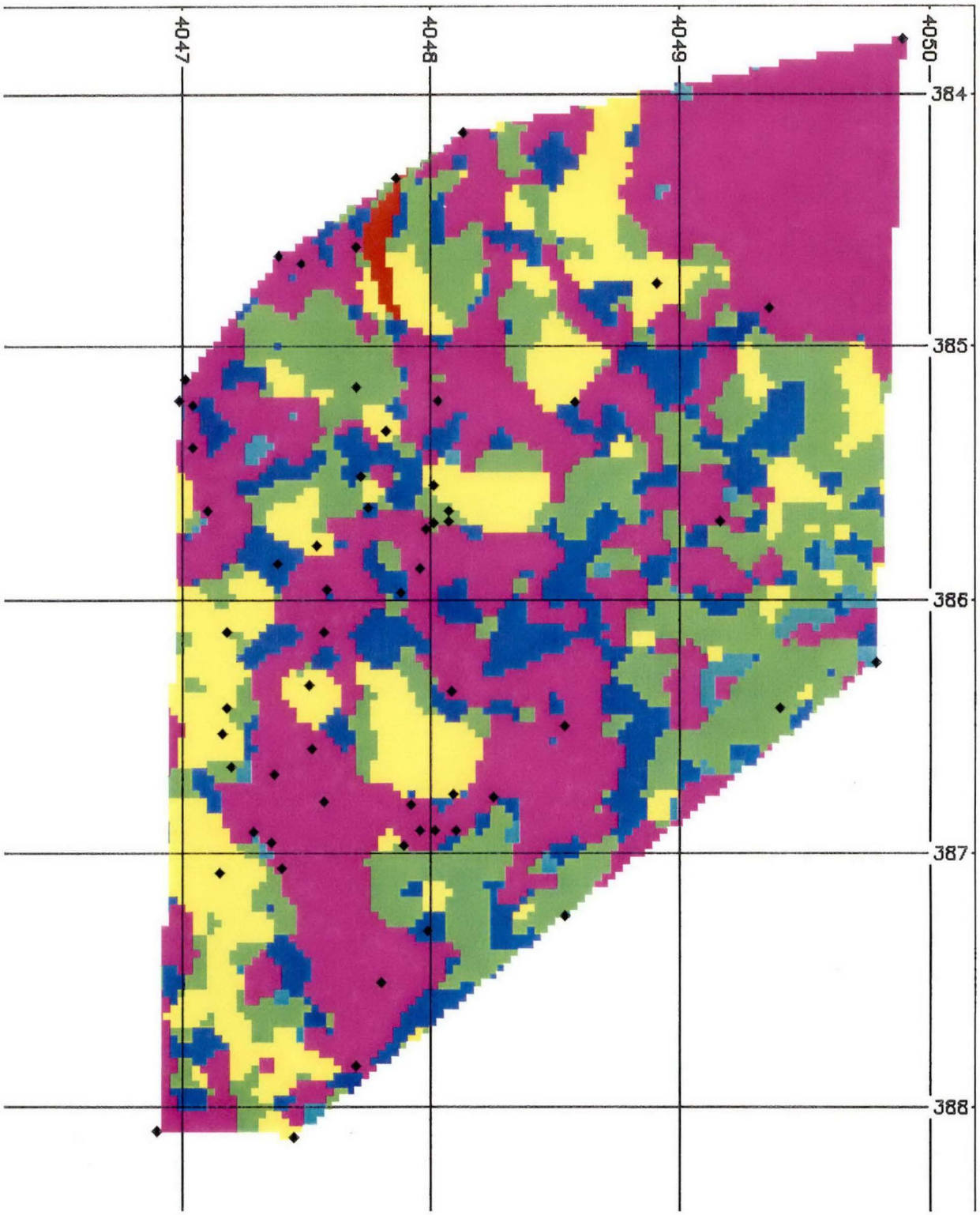
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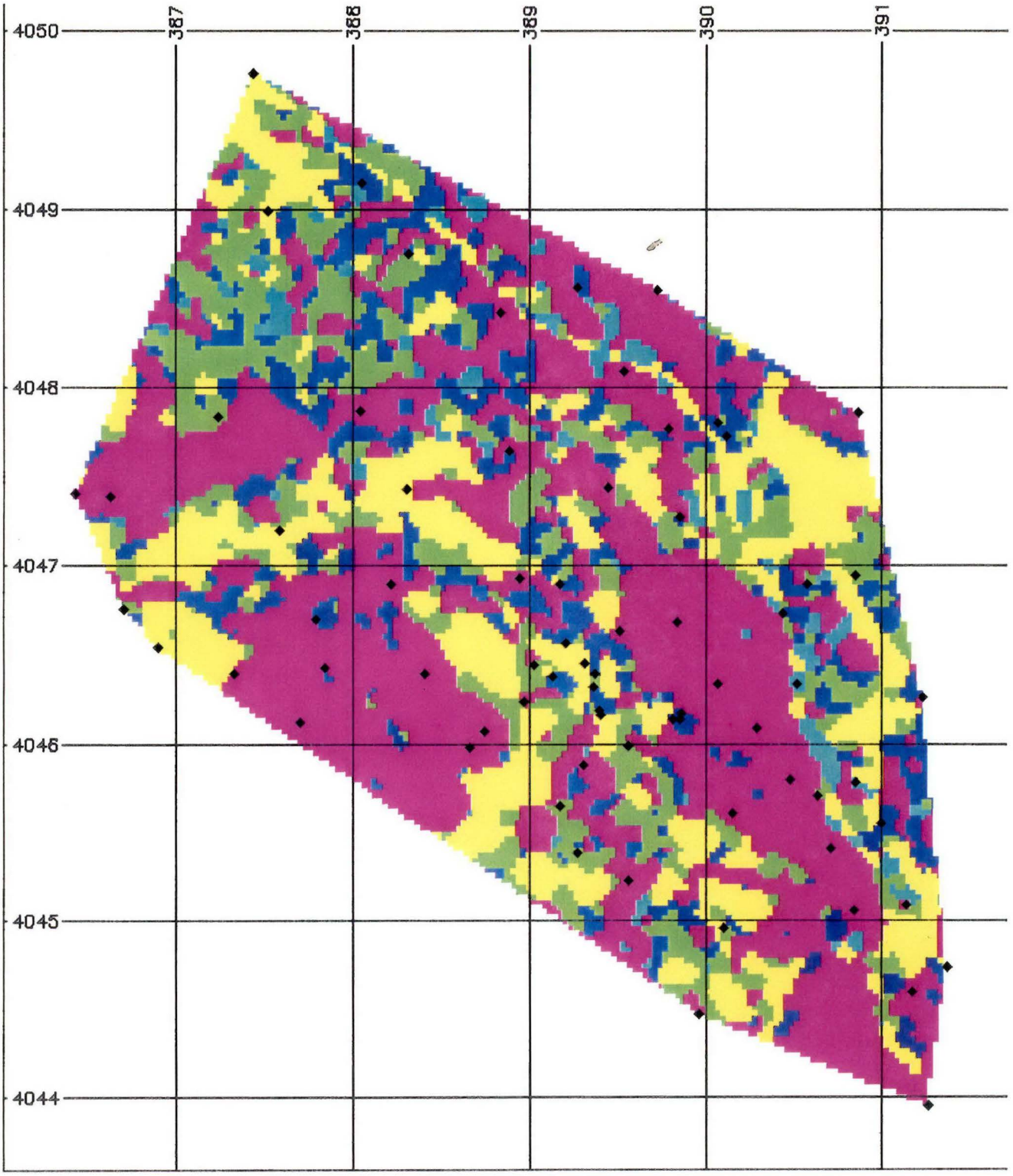
Figure 11. Home range of goshawk number 342, as determined by the minimum convex polygon method, on the Kaibab Plateau, northern Arizona, in 1992. Hawk locations are represented by black squares. Yellow represents areas with <15% canopy closure of ponderosa pine (CC), green represents areas with 15-33% CC, light blue represents areas with <33% CC with a dense deciduous understory, dark blue represents areas with 34-55% CC, magenta represents areas with >55% CC, and red represents areas dominated by pinyon-juniper. Canopy closure was estimated from aerial photographs. A grid of UTM coordinates is superimposed over the home range.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APPENDIX II

INTRODUCTION

In the following section, additional analyses are discussed that may be of interest to Forest Service managers and researchers that have access to Forest Service databases. At the request of the staff of the Kaibab National Forest we present here the results of our analyses of goshawk use of habitat overlays generated from the stand database from the Kaibab National Forest. The goal of this section was to evaluate goshawk use of forested areas relative to: a) categories of stand density index (SDI), b) density of large trees >45 cm DBH, and c) different combinations of overstory and understory tree density. An ancillary goal was to evaluate the usefulness of stand level data in addressing wildlife habitat issues.

METHODS

The statistical methods and study area are identical to the methods presented in the main body of the report except where explicitly mentioned below.

HABITAT CATEGORIES

Data from the Kaibab National Forest stand data base were used to generate habitat overlays for the study area. The land cover data used were for each administrative stand on the forest. A stand is a defined area that shares forest characteristics, as determined by USDA Forest Service employees from aerial photographs and ground surveys. Stands ranged in size from 0.4

ha to 577.7 ha (x= 55.1, SD = 69.9). Vegetation characteristics were measured at a variable number of points (usually between 5 and 20) located within each stand and averaged to provide a single value for each variable in each stand. Stand data were collected by a number of different observers over a period of at least 5 years.

Information from the stand database used in this study included tree density for 5 size classes (Table A1) and stand density index (SDI) (Reineke 1933). This database provided habitat data for approximately 90% of the area within each home range. Because the majority of areas that contained no data were areas with little or no marketable timber (J. Ellenwood pers. comm.) these areas were lumped with the lowest tree density classes for the SDI analyses.

We created three overlays from the stand data: the first was based on SDI, the second on the density of overstory and understory trees, and the third on the density of trees with a DBH >45 cm. The SDI overlay consisted of each stand's mean SDI value reclassed into 6 categories: 1) <65.1 and no data, 2) 65.1 - 110.0, 3) 110.1 - 145.0, 4) 145.1 - 170.0, 5) 170.1 - 190.0, 6) >190.0.

The stand database did not classify trees as overstory and understory. Therefore, we arbitrarily grouped all trees >30 cm dbh as overstory trees and those <30 cm DBH as understory trees. The overstory and understory overlay was created by adding the

stand average for the number of trees per acre for size classes 4, 5 and 6 (Table A1) to provide an average number of trees >30 cm DBH (OS = rough index of overstory trees) for the stand. The corresponding values for size classes 2 and 3 were summed to provide the number of trees <30 cm dbh (US = a rough index of understory trees). For OS, a value greater than 52 trees per acre was considered dense, between 52 and 30 moderate, and less than 30 open. For US, a value of greater than 280 trees per acre was considered dense, between 280 and 125 moderate and less than 125 open. The overlay (OSXUS) was generated by crossing these two categories to obtain 9 combinations of OS and US density. Areas of pinyon juniper, open areas and areas with no data were lumped into category 10.

A third overlay was generated based on the density of trees greater than 45 cm dbh (T5T6). The map was created by adding the values for size class 5 and 6 to get an average number of large trees per acre for the stand. The resulting map was then reclassed so that each stand was assigned to one of 5 categories based on the density of large trees: 1) <5, 2) 5.1 - 10.0, 3) 10.1 - 20.0, 4) 20.1 - 30.0, and 5) >30.0 trees per acre. Areas dominated by pinyon-juniper woodland were lumped with category 1 and areas with no data were assigned to category 6.

Circles of 6,000 acres were generated centered on the nest of each bird (n=11). The amount of overlap of the 6,000 acre circles and the home range was calculated for each bird.

RESULTS

HABITAT USE BY INDIVIDUAL BIRDS

There were no clear trends in use of SDI categories, although areas with SDI between 65 and 110 were used less than expected by 2 birds (Table A2). Some of the 10 categories in the OSXUS overlay occurred too infrequently in the home-ranges to be statistically tested so they were lumped to provide a total of 6 categories (Table A3). Areas with few trees (OS=open, US=open) were used less than expected by 3 of the 11 birds (Table A3). All other categories were used either more or less than expected by only a single bird, or were used more than expected by some birds and less than expected by others. Four birds tended to use stands with less than 10 large trees per acre less than expected and/or stands with >20 large trees per acre more than expected (Table A4).

AVERAGE RANK OF RELATIVE PREFERENCES OF ALL BIRDS

There were no differences between the average ranks of relative preference for the categories of the OSXUS (T_2 = 1.48 [for circles], T_2 = 1.54 [for points], df_1 = 5, df_2 = 50, $\underline{P} > 0.1$ [for circles and points]) or T5T6 (T_2 = 2.18 [for circles], T_2 = 1.14 [for points], df_1 = 5, df_2 = 50, $\underline{P} > 0.1$ [for circles and points]) overlays. For the SDI overlay, analysis of both the 90 m circles and locations suggested that preference increased with SDI (T_2 = 6.46 [for circles], T_2 = 5.34 [for points], df_1 = 5, df_2 = 50, $\underline{P} < 0.001$ [for circles and points]; Table A5).

Specifically, stands with an SDI value <110 were preferred less than stands with SDI values >145, and stands with SDI values between 170 and 190 were preferred the most.

LIMITS OF THE HABITAT DATA

The data used to create the SDI, OSXUS and T5T6 overlays were not collected specifically for this study, and there may be a number of problems with the scale and accuracy of these data. Stand characteristics were measured at only 5 to 20 points and extrapolated to provide an average for the entire stand, which may range up to 500 ha. Sampling intensity may not have been adequate to define habitat categories on an appropriate scale. Furthermore, because stand boundaries and forest structure data were determined or collected by different people over a number of years, there are probably errors and inconsistencies that are impossible to quantify without extensive ground-truthing. As a result, we have much less faith in the few patterns presented here, in Appendix II, than we do in the results presented in the main body of the report.

COMPARISON OF 6,000 ACRE CIRCLES TO HOME-RANGES

The majority of each home range was contained within a 6,000 acre circle around each nest (x=86%, SD=10.4, range 69.2%-99.9%).

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

Conflicting trends of use versus availability were found among individual birds for 5 of the 18 habitat categories examined (with at least one conflict occurring for each overlay). We can

not be certain if this lack of pattern is the result of different birds' preference for the different habitat categories, chance, or the limitations of the data. Because conflicting patterns of this type were not common for any of the three overlays analyzed in the main body of the report, we suspect that the resolution of the data may be too coarse to accurately detect the habitat characteristics being used by goshawks. If this is true, the usefulness of Forest Service stand databases for addressing habitat use by goshawks may be limited.

We did detect a pattern in the use of SDI categories when ranks of relative preferences for all birds were averaged. McTague and Patton (1989) suggested that SDI may be a useful measure of wildlife habitat, but it should be cautioned that SDI was developed to describe even-aged stands where the growing area is completely occupied (Reineke 1933). Under these conditions, the structure of a stand can be predicted given only the mean diameter of trees and tree density. In uneven aged forests that have been subjected to timber harvest, mean diameter and tree density no longer adequately define forest structure. For example, an area with 10 trees of 25 cm DBH per acre has the same SDI as an area with 5 trees per acre of 5 cm DBH and 5 trees per acre of 45 cm DBH. For these reasons we advise caution when interpreting the patterns of use of SDI categories found in this study.

The findings of our canopy closure analysis (main body of

report) and the SDI (Appendix) are potentially related. C. Beyerhelm (pers. comm., US Forest service, Coconino National Forest) found that canopy closure correlated closely with SDI on the Kaibab National Forest and that 55% crown closure (as measured with a spherical densiometer) was, on average, equal to an SDI value of about 155.

Our recommendation (main body of report) to maintain relatively high canopy closure in a significant portion of areas managed for foraging goshawks is supported by the finding that the 3 SDI categories most preferred by goshawks were greater than 145 SDI (about a 50% crown closure based on measures with a spherical densiometer, C. Beyerhelm, pers. comm.). Our finding that the majority of each of the home ranges (x=86%) we studied was encompassed by the proposed 6,000 acre management zone (Reynolds et al. 1992) suggests that the guidelines adequately define the areas that are relevant to goshawks.

LITERATURE CITED

McTague, J. P. and D. R. Patton. 1989. Stand density index and its application in describing wildlife habitat. Wildl. Soc. Bull. 17:58-62.

Reineke, L. H. 1933. Perfecting a stand density index for even-aged forests. J. Agric. Res. 46:627-638.

Reynolds, R. T., R. T. Graham, M. H. Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce, Jr., G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management recommendations for the northern

goshawk in the southwestern United States. U.S. Dep. Agric., For. Serv. Southwest. Reg. Gen. Tech. Rep. RM-217. 90pp.

TABLE A1. Tree size classes used in the Kaibab National Forest's stand database.

Size class	DBH (cm)
2	2.5 - 12.5
3	12.5 - 30.0
4	30.0 - 45.0
5	45.0 - 60.0
6	> 60.0

TABLE A2. Habitat use by northern goshawks in 1991 and 1992 with respect to stand density index on the North Kaibab Ranger District, Kaibab National Forest, northern Arizona. Habitat use was evaluated for goshawk locations and 90 m circles around these locations with the Chi-square test ($P < 0.05$) and 95% Bonferroni confidence intervals (Neu et al. 1974).

	Stand Density Index					
	<65.0[a]	65-110	110-145	145-170	170-190	>190
66	0/0[b]	-/-	+/+	-/-	0/0	0/0
141	0/0	-/-	-/-	0/0	0/0	0/0
223	0/0	0/0	-/-	0/0	0/0	0/0
237	-/0	0/0	0/0	0/0	0/0	0/0

[a] This category also includes all open areas and areas with no data.

[b] - = areas used than expected, 0 = used as expected, + = used more than expected. Results are presented for locations/ 90 m radius circles.

TABLE A3. Habitat use by northern goshawks in 1991 and 1992 with respect to the density of trees greater than and less than 30 cm DBH for stands on the North Kaibab Ranger District, Kaibab National Forest, northern Arizona. Habitat use was evaluated for goshawk locations and 90 m circles around these locations using the Chi-square test ($\underline{P} < 0.05$) and 95% Bonferroni confidence intervals (Neu et al. 1974).

	Tree Density					
	OS dense[a]	OS medium[b] US open	OS medium[c] US medium, dense	OS open[d] US open	OS open[e] US medium, dense	no data,pj[f] open area
66	0/0[g]	0/0	0/0	-/0	0/0	0/0
141	0/0	-/-	+/+	-/-	0/0	0/0
237	-/0	0/0	+/0	0/0	0/0	-/0
273	0/0	+/0	-/-	-/0	0/0	0/0
274	0/0	-/-	0/0	0/0	+/+	0/0
333	0/0	0/0	0/0	0/0	-/0	0/0

[a] >52 trees per acre (TPA) of >30cm DBH.

[b] 30-52 TPA >30cm DBH and >125 TPA <30cm DBH.

[c] 30-52 TPA >30cm DBH and <125 TPA <30cm DBH.

[d] <30 TPA >30cm DBH and <125 TPA <30cm DBH.

[e] <30 TPA >30cm DBH and >125 TPA <30cm DBH.

[f] This category contains the areas without data, the pinyon juniper woodland and naturally occurring open areas.

[g] - = areas used less than expected, 0 = used as expected, + = used more than expected. Results are presented for locations/ 90 m radius circles.

TABLE A4. Habitat use by northern goshawks in 1991 and 1992 with respect to the density of trees >45 cm DBH for stands on the North Kaibab Ranger District, Kaibab National Forest, northern Arizona. Habitat use was evaluated for goshawk locations and 90 m circles around these locations with the Chi-square test ($P < 0.05$) and 95% Bonferroni confidence intervals (Neu et al. 1974).

	Trees Per Acre				
Bird <5[a]	5-10	10-20	20-30	>30	no data
141 -/0[b]	0/0	0/0	0/0	+/+	0/0
223 0/-	0/0	0/0	0/0	0/0	0/0
237 -/0	0/0	0/0	0/0	0/0	0/0
273 0/0	-/-	0/0	+/+	-/0	0/0
333 -/0	-/-	0/0	+/+	0/0	0/0

[a] This category includes open areas and areas dominated by pinyon-juniper woodlands.

[b] - = areas used less than expected, 0 = used as expected, + = used more than expected. Results are presented for locations/ 90 m radius circles.

TABLE A5. Mean values for the rank of relative preference for six categories of stand density index for 11 male northern goshawks in 1991 and 1992 on the North Kaibab Ranger District, Kaibab National Forest, northern Arizona. *P*-values for the Friedman test are provided. Means that do not differ significantly, as determined by Fisher's least significant difference, share a common underline.

	Stand Density Index							
	65-110	<65[a]	110-145	145-170	>190	170-190	*n*	*P*
Circles	2.00	2.54	3.09	3.82	4.45	5.09	11	<0.001
Locations	2.00	2.64	3.09	4.09	4.27	4.91	11	<0.001

[a] This category also includes all open areas and areas with no data.